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SAHARA F_1, AN INDETERMINATE TOMATO HYBRID SUITABLE FOR CULTIVATION IN VIRUS CONDUCIVE ENVIRONMENT

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SUMMARY

Tomato cultivation is restricted due to temperature extremes coupled with susceptibility to diseases, especially viruses. This leads to the erratic tomato availability in Pakistan. Breeding initiatives sought to overcome such problems, resulting in an indigenously developed indeterminate tomato hybrid named Sahara F_1 approved by the Punjab Seed Council for general cultivation during 2021. This hybrid is suitable for cultivation in virus conducive environment. The seedlings of this hybrid experienced raising under an insect net and transplanting in the open around the end of September during autumn, in contrast to previous practice of transplanting around the end of November. During the span of six years—from 2015-16 to 2020-21—various studies related to fruit yield, fruit nutrition, virology, pathology, and entomology ensued in virus prevailing conditions. Sahara F_1 proved itself better than the commercial hybrid in almost all respect, especially resistance against viral diseases. Moreover, its fruit shape, size, and shelf life are appealing for the consumers. The inclusion of the Sahara F_1 in the tomato production scenario of Pakistan will certainly help stabilize the supply and prices of tomato during the lean period.

Keywords: *Solanum lycopersicum*, autumn season, indeterminate, tomato hybrid, virus tolerant, scarcity

Key findings: Newly developed hybrid Sahara F_1 is superior for its performance during virus conducive environment than the existing commercial hybrids available in the market. Therefore, it could be helpful in tomato availability during scarcity period of Punjab (December–February).

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family, one of the most valuable vegetables of Pakistan. Tomato contributes to a healthy and well-balanced diet. It serves as a daily food item and forms an essential component of food consumed worldwide. Tomato is an influential cash and industrial crop in many parts of the world (Noonari *et al*., 2015). Its direct uses are as a salad, a complementary ingredient in many vegetable, meat dishes, cooked in sauces, and for making different products like ketchup, sauces, purees, pulp, juices, and soups, among others. It is a good source of vitamin C (31 mg per 100 g), vitamin A, calcium, and iron (Aidoo *et al*., 2014). Additionally, lycopene is a dominant antioxidant, which is naturally available in tomatoes, beneficial in preventing the growth of various cancer types (Agarwal and Rao, 2000).

The global production of tomato is about 189 million tons obtained from 5.2 million ha, with an average yield of 36.6 t/ha. China and India are the leaders in global tomato production, while Pakistan ranks 30 among the tomato producing countries. In Pakistan, tomato growing has an area of 68,150 ha, producing 802,151 tons, with an average yield of 11.8 t/ha. The yield per unit area of the country is less than the global average (FAOSTAT, 2021). On the other hand, the demand for tomato and its products in the country is expanding at a very high rate of 7.3% yearly, much higher than the increase in its domestic production, causing a ballooning tomato-trade deficit (FAOSTAT, 2021).

The per-unit area low yield is due to non-availability of high-yielding and disease-resistant varieties and hybrids well suited for different seasons. Severe constraints in tomato production are due to temperature extremes and diseases, especially viruses. The regular outbreaks of the tomato leaf curl virus disease (ToLCVD) in autumn can reach up to 100% incidence, with yield losses often exceeding 90% (Saikia and Muniyappa, 1989). Managing viral diseases can result from pesticides application, use of physical barriers, such as nylon nets, and more recently, deploying virus-resistant tomato varieties. However, Pakistan has no existing single virus tolerant variety/hybrid, therefore, requiring importation of resistant variety/hybrid seed (Cheema *et al*., 2013; Ullah *et al*., 2017).

With limited availability of optimum temperature, i.e., 21 °C – 24 °C for vegetative growth, and 14 °C – 24 °C for fruit setting (Geisenberg and Stewart, 1986), and prevalence of viral diseases, it is difficult to grow tomato at one location year round. Therefore, tomato growing throughout the year occurs in different seasons in various pockets across the country. As Punjab is the most populous province of the county, with 53% population (PBS, 2017) producing only 24% of the country's total tomato production, thus, during the rest of the months (July to February), its tomato requirements come from the other provinces, as well as, through imports (PBS, 2022). In Punjab, it is difficult to grow tomato during autumn due to the prevailing high temperature and virus conducive environment; therefore, temperature limitations and vulnerability to viral diseases pose a considerable fluctuation in production and prices.

Therefore, keeping in view the above-mentioned production constraints and demand scenario, efforts commenced to develop tomato pure lines with tolerance against viral diseases and an aim to develop tomato hybrids possessing considerable tolerance against viral diseases. Such hybrids would also help in extending tomato's availability period and reducing tomato seed import. Given the satisfactory performance of the Sahara F_1 previously coded as LITTH-804 in virus prone environment, its approval for general cultivation was a recommendation for the Punjab Province in the 55th meeting of the Punjab Seed Council held on September 20, 2021.

MATERIALS AND METHODS

Breeding background

The hybrid-breeding program in tomato at the Vegetable Research Institute Faisalabad

commenced during the year 2001-02, resulting in developing sufficient numbers of indeterminate pure lines until the end of year 2005-06. The crossing work to develop new local hybrids also began during the same year. The Sahara F_1 development succeeded during the year 2014-15. Its evaluation in a preliminary yield trial progressed at the Vegetable Research Institute, Faisalabad during the year 2015-16. With its encouraging performance against viral diseases, its testing in autumn trials (virus conducive environment) continued for three consecutive years, i.e., 2016-17 to 2018-19, under high tunnels at the Vegetable Research Institute, Faisalabad. Later on, during the autumn of 2019-20 and 2020-21, its assessment used specialized growing technique. This included nursery seedling grown in plastic trays filled with growing media under a tunnel covered with fine insect net and seedling transplanting in a high tunnel at the Vegetable Research Institute, Faisalabad.

Data collection

The data on fruit yield included recording on a plot basis, with few other valuable morphological parameters also recorded. Among these traits, fruit shape index recorded measuring fruit length and fruit width of randomly selected 10 fruits and subsequently computing the ratio by dividing the average of fruit length over fruit width (L/W) (Zhu *et al*., 2022). Fruit firmness of 10 randomly selected fruits comprised the measurement with the help of penetrometer (kg force/cm^2), and then, computing the average. Single fruit weight measuring of randomly selected 10 fruits used a digital weighing balance (g), with the average calculated.

Nutritional analysis

Nutritional analysis of four important tomato fruit constituents, viz., lycopene, beta-carotene, vitamin C, and total sugar, was under the Pakistan Council of Science & Industrial Research (PCSIR), Lahore, during 2019-20 and 2020-21, using the official method of analysis (AOAC, 2016).

Pathological studies

Virology studies transpired with the Plant Virology Section, Plant Pathology Research Institute, Faisalabad, during 2019-20 and 2020-21. The extent of TYLCV incidence reached estimation through a rating scale (Marchant *et al*., 2020). Pathological studies materialized with the Plant Pathology Section, Ayub Agricultural Research Institute, Faisalabad, during 2019-20 and 2020-21. Fungal diseases, such as, early blight, late blight, gray mold, and *Fusarium wilt,* sustained measuring by using different disease rating scales (Pandey *et al*., 2003; Akhtar *et al*., 2012; Gondal *et al*., 2012).

Entomological studies

Entomological studies progressed at the Entomological Research Institute, Faisalabad, during 2019-20 and 2020-21. Measuring fruit borer infestation had the number of infested fruits divided with the total number of fruits. Meanwhile, aphid population estimation used the visual *in situ* counting method.

Statistical analysis

Employing second-order statistics used estimates of variances and covariance's. Analysis of all quantitative traits engaged analysis of variance (Steel and Torrie, 1980) with the MSTATC (Ver. 1.5 Michigan State University, East Lansing, Mich.).

RESULTS AND DISCUSSION

Evaluation of the Sahara F_1 in yield trials

The Sahara F_1, initially coded as LITTH-804, performed better than the check entry, Sahel F_1 (Marketed by Syngenta, International), in different yield trials conducted at the Vegetable Research Institute, Faisalabad from 2015-16 to 2020-21, spanning six years. The summary of these trials is under Table 1.

The results revealed during year 2015-16, the check entry Sahel F_1 significantly

Table 1. Yield comparison of Sahara F_1 and Sahel F_1 at Vegetable Research Institute Faisalabad, Pakistan.

No.	Years	Name of Yield Trial	No. of Entries Tested	Date of Transplanting	Fruit Yield (T/ha)		$LSD_{0.05}$	% increase/ decrease over check
					Sahara F_1	Sahel F_1 (Check)		
1	2015-16	Preliminary	15	04.12.2015 (Normal season)	72.84	90.74	4.83	24.6 (-)
2	2016-17	Station	9	13.10.2016 (Autumn season)	48.55	29.92	4.11	62.3 (+)
3	2017-18	Station	8	21.09.2017 (Autumn season)	53.41	37.86	4.26	41.1 (+)
4	2018-19	Station	7	14.09.2018 (Autumn season)	57.19	38.64	4.85	48.0 (+)
5	2019-20	Station	11	24.09.2019 (Autumn season)	129.21	107.21	4.24	20.5 (+)
6	2020-21	Station	7	28.10.2020 (Autumn season)	123.76	112.37	5.97	10.1 (+)
Means					80.83	69.46	-	16.4 (+)

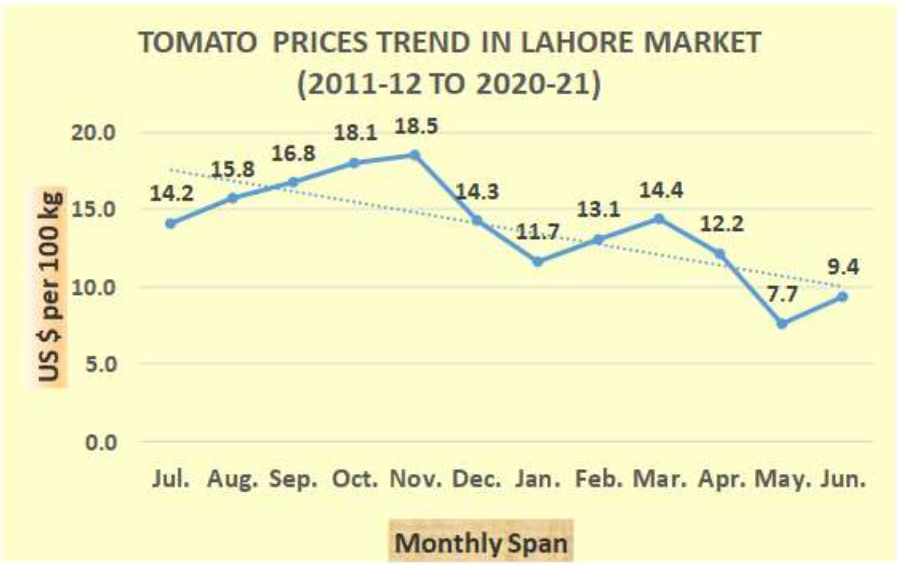

Figure 1. Price trend in Punjab Province, Pakistan.

surpassed Sahara F_1 by 24.6% for fruit yield (123.3 t/ha) when planted in the normal season (Table 1). However, keeping in view the tomato scarcity period/price trend in Punjab Province, as shown in Figure 1 (FVCSP, 2011-2021), and the prevalence of viral diseases during autumn, a decision arose to evaluate the tomato hybrid entries during autumn. Although, Sahel F_1 is a high-yielding hybrid, giving 24.6% higher yield than the Sahara F_1 when sown in normal season during the year 2015-16 (Table 1). However, when tested in autumn of 2016-17 to 2020-21, the Sahara F_1 out yielded Sahel F_1 significantly, with an increase in yield ranging from 10.1%–62.3%. The yield reduction in Sahel F_1 is due to plants with viral diseases and comparatively, the better yield performance of the Sahara F_1 during autumn appears to be due to tolerance against viral diseases. These findings gain

support from the results of Hameed (1995) and Ullah *et al*. (2017). However, on overall basis including normal season, Sahara F_1 produced 16.4% higher yield than the Sahel F_1 (Farooq *et al*., 1993; Talukder *et al*., 2023).

It is evident from the details in Table 2, fruit shape index, an indicator of fruit shape for the Sahara F_1 (1.21) is higher than the check entry Sahel F_1 (1.17), which depicts its higher acceptance in the market. The fruit firmness, an indirect measure of shelf life of the Sahara F_1 is 3.82 kg/cm^2, slightly better than the check entry Sahel F_1, showing 3.80 kg/cm^2. Concerning average single fruit weight, the value of the Sahara F_1 (78.6 g) is less than the value of the Sahel F_1 (97.4 g). Although, the fruit weight of the Sahara F_1 is comparatively less, it is quite acceptable in local markets keeping in view the consumer's perspective.

Nutritional analysis of the tomato fruit

Tomato is a rich source of nutritional components required to fulfill the human daily dietary needs. Estimating the important nutritional constituents, viz., lycopene, vitamin C, total sugars, and B-carotenes present in the tomato (Radzevicius *et al*., 2009; Kumar *et al*., 2015; Javed *et al*., 2022), analyzing the Sahara F_1 and Sahel F_1 fruit samples ensued in an Authorized Testing Lab following a procedure by Aguirre and Cabrer (2012). The results indicated two of the most essential nutritional traits, i.e., lycopene and vitamin C are higher in the Sahara F_1, showing 2.36 mg/100 g and 67.22 mg/100 g, respectively, than with the check entry Sahel F_1. The latter possessed 1.12 mg/100 g and 40.97 mg/100 g, respectively (Table 3). However, the check entry Sahel F_1 contains comparatively higher value for total sugar and beta-carotene than the Sahara F_1.

Virological studies

Among biotic stress, prevalence of viral diseases leads to yield reduction, ranging from 20% to 90% (Hameed, 1995). Therefore, considering the frequency of viral diseases, a serious threat to tomato production during autumn, the data recording on the most common viral disease — TYLCV (Tomato Yellow Leaf Curl Virus)— occurred (Table 4). The results further indicated the years the Sahara F_1 has shown significant tolerance against TYLCV diseases versus with the check entry Sahel F_1. Basing on two years average (Table 4), only 6.9% plants of the Sahara F_1 showed symptoms of TYLCV disease, while 51.9% plants of the check entry Sahel F_1 suffered from the TYLCV disease. This explains the higher yield produced by the Sahara F_1 during autumn. The disease appearance on 51.9% plants of Sahel F_1 in autumn has proven viral diseases are major threats to tomato production during virus prevailing environment. Additionally, emergence of viral symptoms also led to yield reduction in the Sahel F_1 compared with the Sahara F_1, ranging from 10.1% to 62.3% when grown during virus conducive season or autumn.

Pathological studies

The data recording has occurred for four most common fungal diseases of tomato. Regarding this, no serious disease prevalence has been notable on the Sahara F_1 (Table 5). According to data, the Sahara F_1 has shown better resistance than the check entry Sahel F_1 for four major fungal diseases during two consecutive study years.

Entomological studies

No serious attack of insect pest on the Sahara F_1 emerged, as recorded by the Entomological Research Institute, Faisalabad. However, negligible attack of fruit borer and aphid were evident (Table 6). The results further enunciated the prevalence of fruit borer and aphid on tomato plants of both hybrids. However, comparatively less attack of both insects was prominent in the Sahara F_1 compared to the check entry Sahel F_1.

Botanical description of newly developed hybrid: Sahara F_1

The botanical description of the newly developed hybrid, Sahara F_1, is available in Table 7.

Table 2. Salient traits of Sahara F_1 and Sahel F_1 from 2015-16 to 2020-21.

No.	Years	Fruit shape index (L/W)		Fruit firmness (kg force/cm^2)		Single fruit weight (g)	
		Sahara F_1	Sahel F_1	Sahara F_1	Sahel F_1	Sahara F_1	Sahel F_1
1	2015-16	1.20	1.15	3.81	3.79	78.8	97.5
2	2016-17	1.22	1.19	3.83	3.81	76.8	96.1
3	2017-18	1.23	1.20	3.80	3.78	77.8	95.6
4	2018-19	1.19	1.14	3.84	3.82	77.9	96.6
5	2019-20	1.18	1.14	3.82	3.80	80.6	99.8
6	2020-21	1.24	1.20	3.82	3.80	79.8	98.7

Table 3. Nutritional analysis of tomato fruit conducted by the Pakistan Council of Science & Industrial Research (PCSIR), Lahore, during 2019-20 to 2020-21.

Hybrids	Lycopene (mg/100 g)	Vitamin C (mg/100 g)	Total Sugar (%)	Beta Carotene (mg/100 g)
Sahara F_1	2.36	67.22	5.55	0.29
Sahel F_1	1.12	40.97	5.88	0.50

Table 4. Virus incidence on LITTH-804 (Sahara F_1) recorded by the Plant Virology Section, Plant Pathology Research Institute, Faisalabad, during 2019-20 and 2020-21.

No.	Years	Virus	LITTH-804	Sahel F_1
1	2019-20	TYLCV	9.8%	71.8%
2	2020-21	TYLCV	4.0%	32.0%
Means			6.9%	51.9%

Table 5. Disease incidence on LITTH-804 (Sahara F_1) recorded by the Plant Pathology Section, Ayub Agricultural Research Institute, Faisalabad.

No.	Years	Disease	LITTH-804	Sahel F_1
1	2019-20	Late blight	Moderately Resistant	Moderately Susceptible
		Early blight	Moderately Resistant	Moderately Resistant
		Gray mold	Moderately Resistant	Moderately Susceptible
		Fusarium wilt	Resistant	Moderately Susceptible
2	2020-21	Late blight	Moderately Resistant	Moderately Susceptible
		Early blight	Moderately Resistant	Moderately Resistant
		Gray mold	Moderately Resistant	Moderately Susceptible
		Fusarium wilt	Resistant	Moderately Susceptible

Table 6. Pests infestation data on LITTH-804 (Sahara F_1) recorded by the Entomological Research Institute, AARI, Faisalabad, during 2019-20 to 2020-21.

Entries	Fruit borer (% infestation)	Aphid (Population per leaf)
Sahara F_1	10.5	3.8
Sahel F_1	13.6	4.7

Table 7. Botanical description of Sahara F_1.

No.	Botanical features	Sahara F_1	Sahel F_1
Adult plant			
1	Growth habit	Trailing	Trailing
2	Growth type	Indeterminate	Indeterminate
3	Average plant height (cm)	300	285
4	Average stem thickness (mm)	20.3	20.9
5	Stem hairiness	Medium	Medium
6	Stem anthocyanin	Weak	Weak
7	Leaf color	Green	Green
8	Leaf length (cm)	14.5	15.8
9	Leaf width (cm)	7.4	8.0
Flower			
10	Days to 50% flowering	44	47
11	Flower color	Yellow	Yellow
12	Flower size	Medium	Medium
13	Calyx color	Green	Green
14	Anther color	Yellow	Yellow
Fruit			
15	Days to 50% fruit setting	75	80
16	Fruit color	Red	Red
17	Fruit shape	Oblong (Obovoid)	Oblong (Obovoid)
18	Fruit size	Medium	Large
19	Fruit length (cm)	5.3	6.3
20	Fruit width (cm)	4.4	5.4
21	Fruit shape index (L/W)	1.21	1.17
22	Fruit ribs	Weak	Weak
23	Fruit top	Flat	Flat
24	Fruit firmness (kg/cm^2)	3.82	3.80
25	Average single fruit weight (g)	78.6	97.4
26	Average fruit yield (T/ha)	80.83	69.46
27	Potential fruit yield (T/ha)	129.21	112.37
Seed			
28	Seed color	Light brown	Light brown
29	Seed shape	Semi-round compressed	Semi-round compressed
30	Seed size	Bold	Bold
31	1000-seed weight (g)	2.54	3.00

CONCLUSIONS

The study concluded newly developed hybrid Sahara F_1 was superior based on its performance during virus conducive environment than the existing commercial hybrids available in the market. Thus, it could be helpful in tomato availability during scarcity period in Punjab (December-February).

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